Materials & Coatings

Temperature-Sensitive Coating Sensor Based on Hematite

This inexpensive, robust sensor system enables easier measurement and interpretation for optical detection.

John H. Glenn Research Center, Cleveland, Ohio

A temperature-sensitive coating, based on hematite (iron III oxide), has been developed to measure surface temperature using spectral techniques. The hematite powder is added to a binder that allows the mixture to be painted on the surface of a test specimen. The coating dynamically changes its relative spectral makeup or color with changes in temperature. The color changes from a reddish-brown appearance at room temperature (25 °C) to a black-gray appearance at temperatures around 600 °C. The color change is reversible and repeatable with temperature cycling from low to high and back to low temperatures. Detection of the spectral changes can be recorded by different sensors, including spectrometers, photodiodes, and cameras. Using a-priori information obtained through calibration experiments in known thermal environments, the color change can then be calibrated to yield accurate quantitative temperature information. Temperature information can be obtained at a point, or over an entire surface, depending on the type of equipment used for data acquisition.

Because this innovation uses spectrophotometry principles of operation, rather than the current methods, which use photoluminescence principles, white light can be used for illumination rather than high-intensity short wavelength excitation. The generation of high-intensity white (or potentially filtered long wavelength light) is much easier, and is used more prevalently for photography and video technologies. In outdoor tests, the Sun can be used for short durations as an illumination source as long as the amplitude remains relatively constant. The reflected light is also much higher in intensity than the emitted light from the inefficient current methods. Having a much brighter surface allows a wider array of detection schemes and devices. Because color change is the principle of operation, the development of high-quality, lower-cost digital cameras can be used for detection, as opposed to the high-cost imagers needed for intensity measurements with the current methods.

Alternative methods of detection are possible to increase the measurement sensitivity. For example, a monochrome camera can be used with an appropriate filter and a radiometric measurement of normalized intensity change that is proportional to the change coating temperature. Using different spectral regions yields different sensitivities and calibration curves for converting intensity change to temperature units. Alternatively, using a color camera, a ratio of the standard red, green, and blue outputs can be used as a self-referenced change. The blue region (<500 nm) does not change nearly as much as the red region (>575 nm), so a ratio of color intensities will yield a calibrated temperature image.

The new temperature sensor coating is easy to apply, is inexpensive, can contour complex shape surfaces, and can be a global surface measurement system based on spectrophotometry. The color change, or relative intensity change, at different colors makes the optical detection under white light illumination, and associated interpretation, much easier to measure and interpret than in the detection systems of the current methods.

This work was done by Timothy J. Bencic of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18761-1.

Standardization of a Volumetric Displacement Measurement for Two-Body Abrasion Scratch Test Data Analysis

A more robust method is proposed that takes into account the full three-dimensional profile of the displaced material.

John H. Glenn Research Center, Cleveland, Ohio

A limitation has been identified in the existing test standards used for making controlled, two-body abrasion scratch measurements based solely on the width of the resultant score on the surface of the material. A new, more robust method is proposed for analyzing a surface scratch that takes into account the full three-dimensional profile of the displaced material. To accomplish this, a set of four volume-displacement metrics was systematically defined by normalizing the overall surface profile to denote statistically the area of relevance, termed the Zone of Interaction. From this baseline, depth of the trough and height of the plowed material are factored into the overall deformation assessment. Proof-of-concept data were collected and analyzed to demonstrate the performance of this proposed methodology. This technique takes advantage of advanced imaging capabilities that allow resolution of the scratched surface to be quantified in greater detail than was previously achievable.

When reviewing existing data analysis techniques for conducting two-body abrasive scratch tests, it was found that the ASTM International Standard G 171 specified a generic metric based only on visually determined scratch width as a way to compare abraded materials. A limitation to this method was identified in that the scratch width is based on optical surface measurements, manually defined by approximating the boundaries, but does not consider the three-dimensional volume of material that was displaced. With large, potentially irregular deformations occurring on softer materials, it becomes unclear where to systematically determine the scratch width. Specifically, surface scratches on different samples may look the same from a top view, resulting in an identical scratch width measurement, but may vary in actual penetration depth and/or plowing deformation. Therefore, two different scratch profiles would be measured as having identical abrasion properties, although they differ significantly.

With these refined measurements, a wider variety of testing needs can be addressed with greater resolution while using the most appropriate abrasive tip and test material combination for the intended application. The core of this innovation in two-body abrasion research involved scratch testing with ASTM G 171 used as a guideline for determining the number of tests to be conducted. The resultant profiles of each scratch were digitized using an optical interferometer and accompanying software. To accomplish this objective, software code was developed to produce a suite of metrics based on a zero line (ZL) through the scratch, which allowed quantitative definition of the scratch and associated wear metrics.

The computer code determines a ZL through individual cross-sections, then produces the following metrics: Negative Volume Displaced, Positive Volume Displaced, Net Volume Displaced, and Absolute Volume Displaced, along with a secondary set of metrics composed of six roughness parameters that allow definition of the ZL. From these metrics, a Zone of Interaction (ZOI) can be established.

This work was done by K. W. Street, Jr. of Glenn Research Center and R. L. Kobrick and D. M. Klaus of the University of Colorado – Boulder. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18675-1.

Detection of Carbon Monoxide Using Polymer-Carbon Composite Films

NASA's Jet Propulsion Laboratory, Pasadena, California

A carbon monoxide (CO) sensor was developed that can be incorporated into an existing sensing array architecture. The CO sensor is a low-power chemiresistor that operates at room temperature, and the sensor fabrication techniques are compatible with ceramic substrates.

Sensors made from four different polymers were tested: poly (4-vinylpryridine), ethylene-propylene-diene-terpolymer, polyepichlorohydrin, and polyethylene oxide (PEO). The carbon black used for the composite films was Black Pearls 2000, a furnace black made by the Cabot Corporation. Polymers and carbon black were used as received. In fact, only two of these sensors showed a good response to CO. The poly (4-vinylpryridine) sensor is noisy, but it does respond to the CO above 200 ppm. The polyepichlorohydrin sensor is less noisy and shows good response down to 100 ppm.

This work was done by Margie L. Homer, Margaret A. Ryan, and Liana M. Lara of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47612

Substituted Quaternary Ammonium Salts Improve Low-Temperature Performance of Double-Layer Capacitors

Low cell resistances are observed when used with modified acetonitrile electrolyte blends.

NASA's Jet Propulsion Laboratory, Pasadena, California

Double-layer capacitors are unique energy storage devices, capable of supporting large current pulses as well as a very high number of charging and discharging cycles. The performance of double-layer capacitors is highly dependent on the nature of the electrolyte system used. Many applications, including for electric and fuel cell vehicles, back-up diesel generators, wind generator pitch control back-up power systems, environmental and structural distributed sensors, and spacecraft avionics, can potentially benefit from the use of double-layer capacitors with lower equivalent series resistances (ESRs) over wider temperature limits. Higher ESRs result in decreased power output, which is a particular problem at lower temperatures. Commercially available cells are typically rated for operation down to only –40 °C.

Previous briefs [for example, "Low Temperature Supercapacitors" (NPO-44386), *NASA Tech Briefs,* Vol. 32, No. 7 (July 2008), p. 32, and "Supercapacitor Electrolyte Solvents With Liquid Range Below –80 °C" (NPO-44855), *NASA Tech Briefs,* Vol. 34, No. 1 (January 2010), p. 44] discussed the use of electrolytes that employed low-melting-point co-solvents to depress the freezing point of traditional acetonitrile-based electrolytes. Using these modified electrolyte formulations can extend the low-temperature operational limit of double-layer capacitors beyond that of commercially avail-